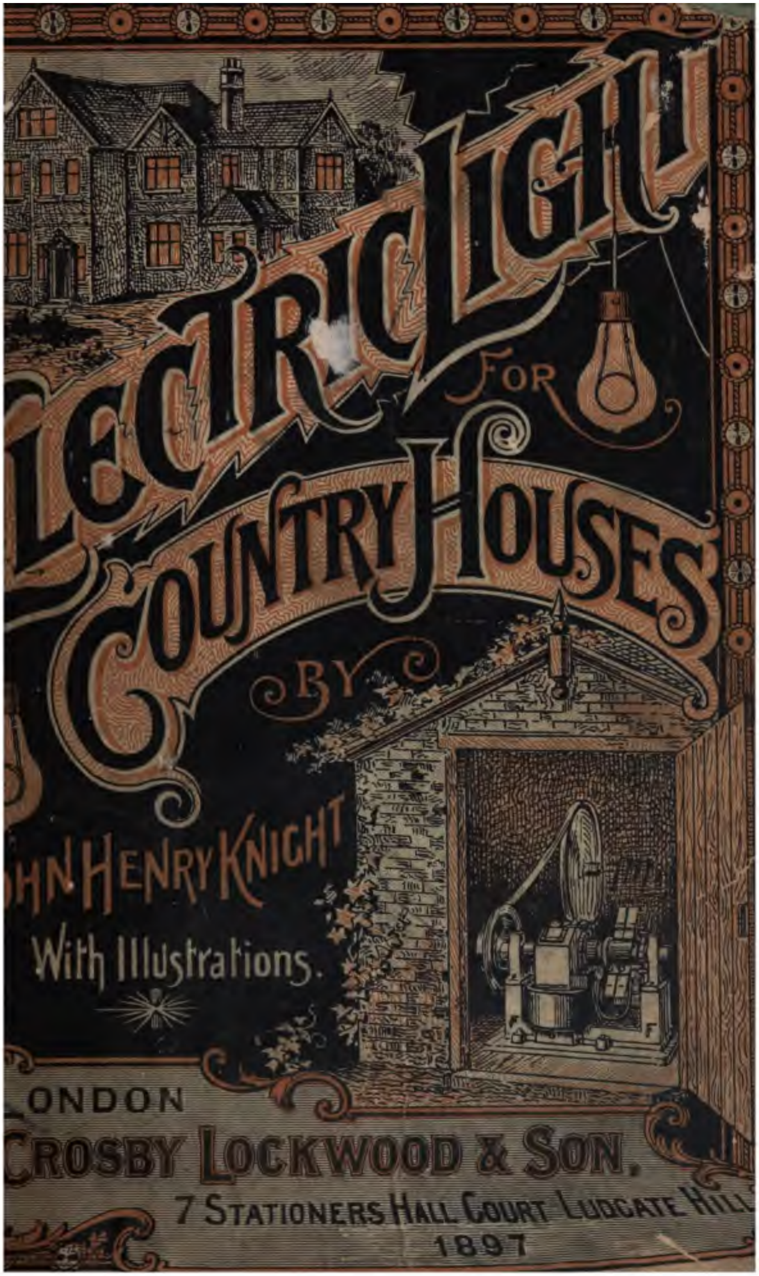
LECTRIC LIGHT
FOR
COUNTRY HOUSES
BY
HN HENRY KNIGHT
With Illustrations.
ONDON
CROSBY LOCKWOOD & SON,
7 STATIONERS HALL COURT LUDGATE HILL
1897

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ELECTRIC LIGHT

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A PRACTICAL HANDBOOK ON THE ERECTION AND RUNNING OF SMALL INSTALLATIONS, WITH PARTICULARS OF THE NECESSARY COST OF PLANT AND WORKING

BY

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ELECTRIC LIGHT

FOR

COUNTRY HOUSES.

CHAPTER I.

INTRODUCTORY.

THREE years ago the author lighted his house with electricity; the success attending that small installation has brought him a great many inquiries from persons living in country districts as to the cost of *running the installation*, and also relating to the management of the engine and dynamo. Many of these questions were answered personally, some by letters to the country papers; but these letters had to be curtailed and the working results of the installation alone given—the methods by which those results were attained had necessarily to be omitted.

1. The practical application of electricity has made enormous strides since the invention of the incan-

descent lamp, which was simultaneously made by Edison and Swan sixteen years ago. The author remembers being present at the first exhibition of the light in London, when Mr Swan read his paper before the Society of Telegraph Engineers. The glow lamp then seemed to have arrived almost before its time,—fittings and switches had to be designed and made; many of the early ones were imperfect. But all this is now changed, and the difficulties of the early eighties have been entirely overcome. Many of the modern fittings are excellent examples of good design and workmanship, particularly when it is considered that they have to be produced cheaply, so cheaply that they must only slightly exceed the cost of gas fittings.

A great many firms will give estimates for wiring a house and fitting up a dynamo and motive power, so that the would-be purchaser can easily ascertain, in a few days, what the total expense will amount to.

Of late years engineers have given a great deal of attention to the accurate governing of engines; lubricators are also fitted of a sufficient capacity for long runs to be made, thus avoiding the necessity of stopping to oil up.

The invention of the oil engine during the last five years has gone a great way to remove some of the greatest obstacles in the way of country house lighting.

2. The cost of a small installation is often thought to be greater than it need be. Sir David Salomons, in his excellent work on Electric Lighting, mentions that the amount spent on lighting his house was £6,000; the smallest estimate given in his work is for

a 25-light plant, and this is rated at £270, which is in excess of what such a plant usually costs. Several installations in the district where the author resides must have cost from £500 to £1,000, but these are for large houses of a rental from £300 to £500 per year.

The author hopes to shew, in the course of this little book, how country and suburban residences may be lighted even more cheaply than they can be by gas, and very little, if at all, in excess of the cost of lighting by paraffin oil lamps,—to say nothing of the coolness, cleanliness, and absolute safety of the electric light when it is properly installed. It must also be remembered that the electric glow lamp consumes no oxygen whatever, nor does it give off any waste products of combustion. *An ordinary gas light consumes* as much oxygen in an hour as six full-grown people!

It is needless to bring forward any further evidence in favour of electric light from a sanitary point of view. Some faddists—particularly those connected with gas companies—have stated that the eyesight is injured by the electric light. In some few cases there may have been some grounds for this assertion, as naked lights were used, and no attempts were made to soften or diffuse the glare. Who would think of using a paraffin, or even a gas lamp, without a globe or shade, especially when in close proximity to the eyes?

The cost of installation in the author's case, where there are in all sixteen lamps in use, did not exceed £90, including an iron shed for the engine and dynamo; but there were special circumstances which allowed the work to be done at this very low cost. These will be referred to later on.

3. The electric light is a luxury, but is rapidly becoming a necessity. Its conveniences are so great that many persons may be tempted to lay down the necessary plant when they find that the cost is not excessive, that the management is very simple, and that there is little to get out of order.

The luxury of obtaining a light by simply turning a switch must be experienced; few people after living in a house lighted by electricity would care to return to gas or oil lamps, with the attendant trouble of filling and trimming them. A paraffin lamp turned up too high, or left smoking by a careless person, may in a very short time so blacken a ceiling that it will be necessary to re-whiten it.

The only accidents that have occurred with electric lighting have been a few fires, and deaths from shock. The former are absolutely preventible by employing respectable and competent people to do the installation work, as these fires are alone caused by bad workmanship—in the same way that gas explosions, which are of a far more frequent occurrence, are more often than not caused by bad gasfitting. "Shocks" are quite impossible in connection with currents used in houses or any interiors, as the Board of Trade will, under no circumstances, allow electricity of a dangerous "tension" to be brought into a house, and the shock afforded by the maximum pressure they allow may be taken with impunity by anyone, and most people would not even consider it unpleasant. The deaths from high tension current shocks have principally taken place in America, where there are a great number of overhead wires. In England they are of

very rare occurrence, as high tension currents are never used in connection with private installations, besides which, conductors conveying high tension currents are now carried underground.

It is a fact that more fires are caused by the upsetting of oil lamps than by all other causes put together. The almost total destruction of Chicago some twenty-five years ago was due to this alone. The damage then done was probably a hundred times greater than the aggregate of all the mischief done by electric lighting from its infancy. In the author's opinion, houses where gas or oil lamps are used are not nearly so safe as those electrically illuminated. Mr Musgrave Heaphy, the Technical Officer of the Phœnix Fire Office, says that "electric light is the safest of all illuminants *when properly installed.*" In many cases where electricity has been adopted, a reduction of the insurance premium has been made. In a large flour mill, which was previously lighted by gas, the reduction of the premium amounted to 10 per cent.; of course in a flour mill lighted with naked lights the risk would be greater than with a private house. The dust which generally pervades the atmosphere of corn-mills has been known to take fire almost as if it were a gas, and so cause a conflagration.

4. It is for those persons who live in houses of a rental from £80 to £200 that this book is intended. Where two or more householders living within a radius of a few hundred yards can agree to join together to erect a private central station, the cost would be correspondingly reduced.

CHAPTER II.

ELECTRICITY AS APPLIED TO LIGHTING.

5. If the reader intends to put down an electric light installation and work it without the assistance of a professed electrician or expert, although a great knowledge of electricity is not imperative, some acquaintance with the subject is not only desirable but necessary.

This book does not pretend to be in the least degree a text-book on electricity. These already abound, and to those who desire to go more deeply into the subject, the author can confidently recommend, amongst many others, the following:—Sprague's "Electricity," and "Electric Lighting" by Holmes, both published by Spon, while Sir David Salomons' work, "Electric Light Installations and the Management of Accumulators," will well repay careful study. The author thinks, however, that a few remarks about current, electromotive force, resistance, &c., may not be out of place.

When electricity is produced either by a dynamo or galvanic battery, a "flow" of current takes place from one terminal to the other when these are connected together by a wire; the electric current proceeds from the "positive" to the "negative." The pressure that

produces this flow, or tends to produce it, is called "electromotive force," usually written E.M.F., and the amount of electricity flowing is usually spoken of as the "current." The degrees of difference of potential or E.M.F. are expressed in "volts," and the quantity of current flowing is expressed in "ampères." The E.M.F. produced by one Daniel's cell of copper and zinc is one volt, and one volt only, even if the cell be only as small as a thimble, or a vat containing many hundred gallons; two Daniel's cells give two volts, and three cells three volts, and so on.

Taking an hydraulic analogy, volts may be compared to the head of water in feet and the resulting pressure therefrom, and ampères to the number of gallons passing. All conductors offer resistance to the passage of electricity,—this resistance being directly proportional to the length, and inversely proportional to the sectional area, of the conductor. The measurement of this resistance is expressed in "ohms," and, to continue our hydraulic analogy, may be compared to the loss of effective head due to friction.

Electricity, strictly speaking, does not flow. The precise action that takes place is not known, but it will be sufficiently accurate for our purpose to assume that the working principle follows the same laws that water does. We know that, practically, a fall of water, say 100 feet high, with a delivery of 50 gallons per minute, will give the same mechanical energy as one of 50 feet high with a delivery of 100 gallons per minute. But supposing one had to convey this water through pipes, the size required for the former would be half that required for the latter. The same may be said for

electricity, and in the case of transmitting the electrical energy to great distances very high voltage is used, with a corresponding reduction in current. When, however, very high voltages are used, the pressure becomes dangerous to life; and in houses, where of course the distances are comparatively very short, the pressure never exceeds 110 volts, is more frequently 100, and very often only 50. Such a pressure as this could not harm an infant, and a shock from a dynamo working at this voltage is hardly even unpleasant. The product of the volts multiplied by the ampères expresses the "activity" of the current, and each voltampère, *i.e.*, 1 volt × 1 ampère, is called a watt. 746 watts constitute 1 electrical horse-power, and requires 1 mechanical horse-power to produce it by means of a dynamo. 1000 watts constitute a Board of Trade "unit." Electricity, when provided by electric supply companies, is usually sold by the unit, in the same way as gas is by the 1000 cubic feet.

6. The lamps generally used on private installations are 50, 60, 80, or 100 volts. These may be termed low voltage currents. The currents of these voltages are perfectly safe to life and limb; but a current of 80 or 100 volts will certainly give a perceptible shock if the two terminals of the dynamo or of a lamp are touched with the hands or fingers.

7. The ampère or measure of current can be shewn by an instrument called an ammeter. Likewise the voltage is shewn by a voltmeter, which really is a galvanometer with an extremely fine and long wire,

the dial being graduated to volts. The fine wire takes only a very small portion of the current of the dynamo or battery; but the ammeter has a very short thick wire, through which the whole of the current is passed.

8. The readings of these two instruments multiplied together give the energy of the electric current in watts. Now, if the voltmeter reads 50 and the ammeter 12, the energy of the current is 600 watts; or, if the voltmeter reads 100 and the ammeter 6, the product is the same.

9. The reader will do well to grasp these technical details, as unless they are understood it is impossible to comprehend the terms that are in use, and these terms will, of course, be meaningless.

The author has met with people to whom these terms conveyed no meaning whatever; the mind did not seem able to grasp the volt and ampère. They would say, "I can tell what an inch or foot is, because I can see it; I know what a lb. weight is, for I feel it," but the electrical measures seemed to be unintelligible to them.

10. The ohm, as before mentioned, is a measure of resistance. About 400 feet of No. 16 S.W.G. copper wire have a resistance of 1 ohm; a mile of No. 8 iron telegraph wire has a resistance of nearly 14 ohms.

11. To return to the electric current: hitherto we have only considered direct currents,—that is, currents

flowing in one direction, one pole of the dynamo being positive and the other negative; as in a battery we have the copper and zinc poles, and the current flowing from the former to the latter.

Alternating currents are those which, instead of flowing continuously from positive to negative, continually change their direction, the terminals of the dynamo being alternately positive or negative.

The advantage of the alternating current is that voltage can be lowered from a very high voltage on the mains to a low voltage for use in the house, by simple instruments without any moving parts; these are called transformers.

Alternating currents are very rarely used in private installations.

12. A shock from an alternating current is far more dangerous than one from a direct current of the same voltage.

The Americans use a voltage of 2,000 volts to execute criminals; but there is no doubt that a somewhat lower electro-motive force would cause death; an accidental shock of 1,000 volts is usually fatal.

The author may be accused of being prejudiced against high voltage alternating currents; but in his opinion there must always be a great risk to attendants of dynamos at stations where they are used, notwithstanding indiarubber gloves and indiarubber boots being provided for the use of those in the dynamo room.

The public have still some dread of sudden death by electricity, and the author has at times met several

people who have raised that objection against electric lighting. He has more than once shewn to visitors in his engine-house that there is no danger in touching both terminals of the 50 volt dynamo with the bare hands ; nor is there the slightest danger with a tension of double this amount.

CHAPTER III.

THE DYNAMO.

13. In 1831, Faraday shewed at the Royal Institution how electricity could be obtained from a permanent magnet and a coil of insulated copper wire.

Practical men took up the idea, and magneto-electric machines were in a few years in use for experimental purposes and for electro-metallurgy, and in many instances the magneto-telegraph superseded that worked by the galvanic battery.

Large magneto machines giving alternating currents were used for electric light both on the Continent and in England. One which was used at the South Foreland lighthouse for some years was shewn at the London International Exhibition of 1862, and it was in use till quite recently.

But the dynamo—that is, a machine in which the magnets are excited or magnetised by a portion of the current—did not appear till some years later. Siemens, Wild, Varley, and Ladd all produced machines which have now been superseded. The type generally adopted at the present day for direct currents is that of Gramme, which latter was patented in England in 1870.

14. Fig. 1 shews a modern dynamo. The armature or ring consist internally of either iron wire or thin sheet-iron stampings, supported on a brass centre or rimless wheel, technically called a spider. Round these iron wires are coiled layers of copper wire, which generate the current. The wires are coiled in

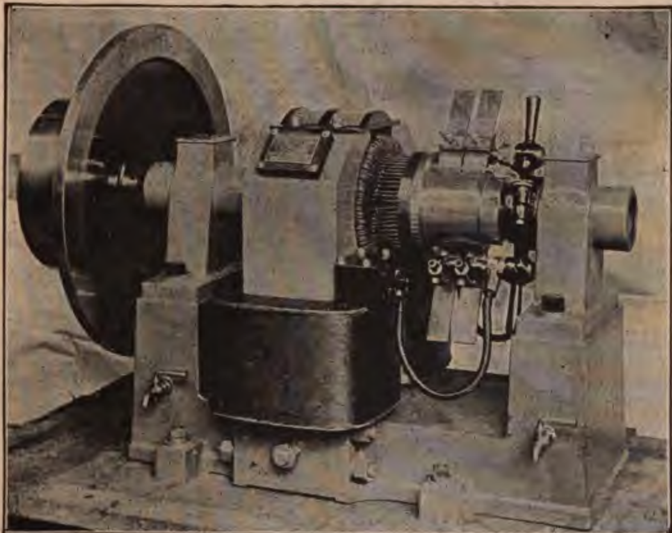

FIG. 1.—A MODERN DYNAMO.

segments of sixteen or more. The ends of the segments are all connected, the inner to the outer of the next so as to make one continuous length of wire; but the ends of each segment are connected to the commutator fixed to the spindle; a drum of copper segments insulated from the spindle and from one another. Brushes of copper wire take the current

from each side of the commutator to the external circuit. These brushes can be set to slightly different angles with the centre of the machine as may be found necessary in running. They are attached to, but insulated from a bar, which has a range of movement of some 15 or 20 degrees. A portion of the current—or in some machines, all of it—goes round the field magnets to induce magnetism therein. The field magnets are simple masses of cast or wrought-iron; they are not permanent magnets.

15. There are three methods in use of exciting the field magnets. 1st The series machine, in which all the current circulates round the field magnets in a stout copper wire making comparatively few turns, say a few hundreds.

16. 2nd. The shunt machine, in which a small portion of the current is shunted into a fine wire of very considerable length round the magnets. This fine wire takes about $\frac{1}{20}$ or $\frac{1}{30}$ of the current generated by the dynamo. It makes several thousand turns round the magnets. The shunt wound machine is used for charging accumulators.

17. 3rd. The compound wound, which is a compromise between the two, having both a long fine wire and a short stout wire. This is the type of machine used for incandescent lighting direct, *i e.*, without the intervention of accumulators, at least in all places where lights have to be switched on and off, as by the two wires wound round the magnets the

current is kept at the same voltage. Of course it is understood that the speed at which the dynamo is driven remains the same.

18. The large dynamos in use in central station work, supplying thousands of lights, do not come within the scope of this book.

19. In choosing a dynamo, it is always best to buy one by a well-known maker; the maker will supply what information is wanted as regards fixing, speed, &c. For use with a gas or oil engine, it is necessary to have a fly-wheel—usually a wrought-iron or cast-iron disc, with a steel band or tyre round it—on the dynamo spindle. Gas and oil engines give only one impulse in every two revolutions, or less when the governor is in action; hence these slight irregularities would cause a slight fluctuation of the light, which is extremely objectionable, were it not for the small fly-wheel on the dynamo, which, running at a very high speed, steadies the machine, and produces a very fairly steady current.

The bearings of the dynamo should be long, and fitted with efficient lubricators. Some makers fit a third bearing outside the driving pulley. This makes a strong and durable machine, but in small machines it seems hardly necessary.

The brushes should be of copper or brass wire gauze, and press lightly and evenly on opposite sides of the commutator.

20. The author cannot advise the reader to pur-

chase the cheap dynamos which are advertised in some of the mechanical papers; doubtless some are worth the money, but often the cheap machine will not be cheap in the end; and the breakdown of a dynamo in the middle of an evening's run is very disappointing, and in the end the outlay for repairing it may really bring its total cost to the price of a first-class machine. Besides, the efficiency of these cheap dynamos is usually low. By efficiency in this case it is meant the ratio of the output of the dynamo to the power expended in driving it.

A good machine should run for years without any outlay for repairs; the cheap machine is a constant source of worry and vexation. Of course, with care and nursing, it may run for some months or a year or two, but a good dynamo should require but little attention or repairs.

21. Many makers send out, or will send on application, a card of directions for working their dynamos, to hang up in the dynamo room.

22. The dynamo must be fixed on a brick or concrete foundation. Small machines may be bolted to a stout floor, but then some means must be taken to check vibration. The author had one at work for some time screwed down to a baulk of timber, which was simply an extension of one of the bearers carrying the engine; but the arrangement was not satisfactory, and was given up after a few months running, a foundation of brick in cement being used instead.

23. A convenient arrangement is to have the dynamo not bolted directly to the brick foundation, but to have it resting on two parallel rails in which are slots to take the heads of the holding-down bolts; this allows the dynamo to be shifted several inches to take up the slack in the belt. Many makers supply these tightening rails and the necessary bolts at an extra cost.

With a small machine it is best to have it raised a foot or eighteen inches from the floor, for with a dynamo on the floor level it is inconvenient to adjust the brushes, or do anything that may be required.

24. The belt from the engine should run with the pulling side downwards, so that the "sag" should be in the upper part. This allows the driven pulley to be embraced by the belt for almost half its diameter. If the pull is at the top, the belt will by no means embrace half the pulley's diameter, and slipping will be more likely to occur. Having the tight side underneath will also prevent the belt lashing the floor. The author's experience in driving dynamos leads him to recommend leather belts in preference to certain cotton belts now in the market. The belt should be as thin as consistent with strength, and pliable. If the belt is too heavy, it will absorb too much power as it passes round the small pulley of the dynamo. If the link belts would stand wear and tear they would doubtless be more largely used.

25. Rope gearing is often used when considerable power is to be transmitted. Ropes run very smoothly,

and are comparatively cheap, but for the small installation a leather belt is probably the best.

26. Slow speed dynamos are coming into use, but they are larger and more expensive than those described above. The great advantage is, that as they can be coupled directly to the crank shaft of a high speed engine, all trouble from belts slipping or coming off is avoided. They are almost universally used on shipboard, partly on account of the small space occupied by the plant. Very frequently in town lighting the dynamos are coupled directly to high speed engines.

27. It must be explained that it is absolutely imperative that the dynamo runs at a uniform speed. It has been shewn above that the voltage of a series of galvanic batteries depends on the number of the cells forming that series, so the voltage of the current from a dynamo will vary as the speed at which it is driven. Of course machines are wound with thick or fine wires for various voltages, some as low as 5 volts for electro metallurgy, and some to thousands of volts for town lighting with transformers.

The electric welding machines, used for welding up channel rims for indiarubber tyre wheels, are said to have as low a voltage as half a volt. The machine will heat two pieces of one-inch iron rod to a welding heat, and weld the same together in about three and a half minutes.

CHAPTER IV.

MOTIVE POWER.

In the present day the user of power has a choice that was unknown to the past generation. Steam and hot-air engines, besides wind, water, and animal power, were the only motive powers in use thirty or forty years ago. Now gas and oil engines are doing work in many places that was formerly done by steam, wind, or water power.

28. The householder who would adopt the electric light, if living in the country, must decide which of these above-named motive powers he will use. Wind and animal power may be dismissed at once. Water power, if it can be had, is probably by far the best motor to use. Lord Armstrong, who was the first individual to adopt the Swan lamp in his private house, used water power. But water power is available in few places only, and often the cost of the dam, and retaining a sufficient head of water, will be a serious expense.

Some twenty-five years since, when the author first visited Switzerland, he could not help noticing the great number of streams that were rushing down the

hillsides, and not used for any purpose. Many of these have now been employed to drive dynamos for lighting or for power purposes; but as England is a very different country from Switzerland, very little power can be obtained from our rivers or streams.

29. If the steam engine is chosen as the motor to drive the dynamo, it is imperative to have one fitted with what is called an electric-light governor. These are of various patterns, but their object is to produce an almost absolute uniformity of speed. The old slow speed governor, which is frequently to be seen on engines of upwards of ten or twelve years of age, was very far from sensitive, and is now replaced by high speed governors.

30. The governor for electric-light engines (except in small engines) should be so constructed to alter the point of cut-off of the steam, *i.e.*, to cause the engine to work more or less expansively.

For the benefit of those who have not grasped what expansion of steam is, the following explanation may be of service:—Assume an engine, with say at least 50 lbs. pressure in the boiler, has its slide valve so arranged that the steam enters the cylinder during the whole stroke of the piston ; such an engine would consume twice the amount of steam, and hence water and fuel, that an engine would in which the steam were "cut off" or stopped from entering the cylinder when the piston had gone half its stroke only. But the latter engine would do more than half the work of the first, the imprisoned steam expanding and pushing on the

piston would give only 20 or 15 per cent. less power than the first engine would. The power would be slightly less, but the saving in fuel would be very considerable. But in practice, in no engines other than compound does the steam enter the cylinder the full length of the stroke of the piston. Even in small cheap engines the steam is cut off at half or five-eighths of the stroke; and a modern governor will so alter the travel of the slide valve, or of a second or subsidiary valve, that the steam will be cut off earlier or later as required by the load on the engine.

31. In a compound engine, steam enters the first or high-pressure cylinder, and expands into the low-pressure cylinder, which is of much larger capacity than the high-pressure. In triple-expansion engines, the expansion is carried out in three cylinders.

The saving in fuel by governing the engine, by altering the cut-off and working expansively, is very greatly in excess of the old method of governing by the throttle-valve.

At the Royal Agricultural Society's trials of small steam-engines at Plymouth in 1890, the first prize was taken by a compound engine by Messrs Simpson and Strickland, of Dartmouth (Kingdon's patent). The coal consumed was 4.099 lbs. per indicated H.-P., or rather less than half of the consumption of the best competing si[illegible] cylinder engine.

32. There a[illegible] forms of steam-engines in the market, a[illegible]ated in the catalogues of the makers, th[illegible]asting space to describe

them. The purchaser of an engine should see that the lubricators are of sufficient capacity for long runs. There may be occasions such as balls, parties, or even in case of illness, where the light may be wanted for twelve or more hours, and the engine must be able to meet any extra demand as a good long run without a stop.

It is well to have plenty of boiler power, so that the engine should not need the close attention of the attendant, and the stoking may be done at considerable intervals.

33 The great advantage of the steam-engine over the gas or oil engine is the cheapness of first cost, and that it is better understood by drivers and the public than gas and oil engines are.

34. The disadvantages are, that repairs frequently are very expensive. A small steam-engine is more expensive to work than a gas-engine, and certainly far more expensive than an oil-engine at the present price of oil. It requires constant attendance; it may be easily damaged by neglect; and after some years the boiler, if not annually inspected by a competent person, becomes positively dangerous. In many cases the quantity of water required adds considerably to the expense of the working, that is if water has to be pumped from a great depth, or if water is scarce.

35. Several attempts have been made to overcome some of these disadvantages, at least as regards

attendance. The Davey motor is a vacuum engine, with steam of only 2 or 3 lbs. pressure; the exhaust steam is led into a surface condenser, and a vacuum is produced; the condensed steam is pumped back again into the boiler; the boilers are fitted with hoppers, somewhat on the principle of the well-known tortoise stoves; the hopper will contain coke for several hours' run. Many of these vacuum engines are at work and giving satisfaction.

36. The Bailey-Fredrich engine is a high-pressure engine, which, like the Davey motor, has a surface condenser, and the condensed steam pumped back into the boiler; a hopper which contains coke for some hours obviates the necessity of frequent stoking. The fire is regulated by a self-acting damper, which is operated by steam pressure as it rises and falls. The author has no practical experience of this ingenious motor; it is made by Messrs W. H. Bailey and Co., of Salford.

37. Another boiler, hardly known in England, but which seems to promise well, is the instantaneous steam-generator of M. Serpollet, of Paris. Flattened steel tubing, in which only a very small passage is left, is bent into a spiral, and several of these, coupled one after the other, are placed above a coke fire, and water being pumped in by the feed-pump, steam is instantaneously generated. These generators are employed in the steam carriages in use in Paris and on the Continent, the fire being replenished from a hopper.

M. Serpollet told the author that he had several at work driving electric light installations. The boiler, if it can be so-called, was tested by Professor Kennedy in London, with favourable results; the steam being considerably superheated is doubtless the cause of its success and economy.

38. Gas is seldom available in country places for driving gas-engines. There are no motors that require less attention, except perhaps wind and water, than a good gas-engine. Instances have often occurred of engines being started and left for ten or twelve hours without any attention, not only occasionally, but continually, day after day.

Unlike the steam-engine, the gas-engine requires to be started by hand (unless fitted with a self-starter), the action of the piston being alternately that of a pump and a motive piston.

At the first outstroke, air and gas are drawn into the cylinder; the next instroke, they are compressed then fired, and the second outstroke or working stroke is made; the last instroke drives out the products of combustion ready for the next out or suction stroke.

39. The chief makers of the gas-engine in England are Messrs Crossley Brothers, of Manchester, but as their Otto patent expired some four or five years since, scores of firms are now making gas-engines.

Until a few years ago, the admission of air and gas to the cylinder, and also the firing, were effected by a slide-valve of very considerable dimensions, and

this slide often gave trouble, and frequently required refacing. As some of these slide-valve engines are, or may still be, in the market, the purchaser of a gas-engine should see that the engine has "mushroom" or lift valves, and that the firing is done by the hot tube.

The firing-tubes when first introduced were of iron, and often gave out after a few days' work; and if this occurred at a time when the engine was running, a stoppage was the result. But tubes are now made of an alloy of nickel and aluminium; these are somewhat expensive, but will last for six or more months in daily use.

40. As the gas in exploding, or, more strictly speaking, burning, presses on one side of the piston only, and that at only each alternate outstroke, the diameter of the cylinder must exceed that of a steam-engine of equal power. The crank, framing, &c., must be very stout, for as the work of the gas-engine is done in one-fourth of the time a steam-engine would do it, the crank is not receiving or transmitting power for three-fourths of its time. All the work being done in so short a space of time, and the high pressure on the piston at starting (sometimes running up to 280 lbs. per square inch), requires an extremely stout crank shaft, with its bearings close up to the cheeks of the crank, and these bearings should be of considerable length.

41. The makers of gas-engines usually send out full instructions for working them. It is impossible

to give instructions here, as the engines of various makers differs so much in detail.

One thing, it may be mentioned, which needs to be guarded against is frost. The cylinders of oil and gas-engines, being water-jacketed to prevent the working parts being overheated, are liable to be cracked or burst by the water in the jacket freezing. During winter months the jackets should be emptied of water every night, or some precaution taken either by keeping a light burning under the cylinder, or covering the cylinder with mats or felt to prevent loss of heat by radiation. The best plan is undoubtedly to empty the jacket; but of course care must be taken not only to turn on the water before starting the engine, but to see that the water in the tank and supply pipes is not frozen. The pipes can be covered by hay or straw bands, which protection will generally be sufficient if the engine is in daily use.

42. A few days after Christmas 1892, the author happened to be calling at the works of certain gas-engine makers, where a very considerable number of cracked jackets had been sent in to be patched if possible, or replaced.

The reader may remember that a sharp frost set in on the night of Christmas day, and doubtless scores of men who had gas-engines in their charge were holiday-keeping; and so the engines being neglected, were damaged by frost. Of course all such accidents must be put down to carelessness: the engine-men should have seen that the jackets were empty before leaving for their holidays. The author has been told

that in Russia and Germany, where the winters are more severe than here, cracked jackets are comparatively rare; the reason being that the men in charge of gas-engines realise what the effect of the frost is, better than persons living in our warmer and more changeable climate.

43. The governing of gas-engines is done on a totally different method to that employed in steam-engines. In the gas-engine, the governor stops the gas entering the cylinder when the speed becomes too great, so that an explosion is missed. Some makers fit what they call an electric-light governor, in which the explosion is not wholly missed, but by admitting only a lesser charge of gas the effort of that explosion is reduced.

44. The governor should be simple. The pendulum or inertia governors of Messrs Crossley, Messrs Fielding and Platt, and of the Trusty Engine Co. Limited, are all good. The governor should consist of as few parts as is consistent with proper working. Very few makers of gas and oil engines now drive the governors by belts or guts. This method is positively dangerous, for if the belt slipped, came off the pulley, or broke, the engine would run away, and considerable damage might be done.

45. The author has heard of an instance of a small engine completely wrecked by running away. The fly-wheel broke into four or five pieces; one piece, weighing about 15 lbs., went through the roof of the

shed; and a man standing by the engine was hurt, fortunately not seriously. With a properly made pendulum or inertia governor, such an accident would be impossible.

46. The oil-engine has been in use for some years in isolated places for electric lighting, and has now passed the experimental state. A modern oil-engine will work as reliably and steadily as a gas-engine. To Messrs Priestman Brothers, of Hull, is undoubtedly due the honour and credit of making and introducing the first commercial oil-engine. As this engine may be considered to belong to the early or experimental days of oil-engines, it is hardly necessary to describe it at length. Some hundreds are in use in various parts of the world, and it has gained a well-earned reputation. It is being manufactured also in the United States.

The principle of this, as well as of all modern engines, is that mineral oil, such as used in lamps, and having a flashing point above 73° Fahr., is vaporised with a small quantity of air drawn into the cylinder, with a further air supply compressed by the piston, fired, and so forcing out the piston as in a gas-engine. It is sometimes stated that the oil is made into oil-gas. This is hardly correct. If oil is made into a permanent gas the tarry products are thrown down (for every oil-gas plant requires a washer or scrubber to get rid of the tar and heavy matter that comes over with the gas). Hence, if the oil is gasified, the piston and cylinder will, in even a few hours' run, become gummed up with the tar and deposit. If the oil is vaporised only—

that is, made into oil-steam and worked in a properly-jacketted cylinder—the engine will run for months without requiring cleaning. To hit the happy medium and make the vaporisers produce vapour of the right temperature, and not to turn the oil into gas, was the task the early makers of oil-engines had to contend with.

47. The difficulty of firing the compressed charge was in the early engines got over by employing the electric spark. A battery and coil were used, and at the proper moment the contact was made and the spark passed between two insulated platinum electrodes in the combustion chamber.

At the present day only one or two English firms use the electric spark, but it is used on the Continent both for gas and light hydro-carbon engines—that is engines using the vapour of gasoline or benzoline in place of gas.

48. There are several excellent oil-engines in the market, each maker claiming his engine to be better than any other. It would be so impossible to describe all the engines, that it is best to describe at length the engine that the author has had some experience with. The Trusty oil-engine, made under the patents of the author and Messrs Weyman and Hitchcock Limited, of Cheltenham, is represented in Fig 2 (*see* frontispiece).

The cylinder and piston are like that of an ordinary gas-engine. The back of the cylinder is not closed with a cover or a water-jacket, but by the vaporiser,

which is simply an iron casting. The passages in which the oil is vaporised surround the combustion space—that is, the hottest part of the cylinder. A valve, worked by a cam on the counter-shaft, admits the vapour and air into the cylinder as required. The same cam also works a small oil-pump, which delivers a few drops of oil at each stroke into the vaporiser. The governor, of the inertia or pendulum type, causes the valve to remain closed and the pump to miss a stroke if the speed becomes too great.

49. Before starting the engine, the vaporiser is first heated, and this, in the small engines, takes about seven or eight minutes, or twelve or fifteen minutes in the larger ones, by an oil blast-lamp.

The firing is effected by a hot tube, generally made of a special alloy. The tube is kept hot by a lamp and blow-pipe, the air for the blow-pipe being provided by a small air-pump worked by the engine. The container for the lamp for heating the firing tube will hold sufficient oil for five or six hours' run, and can easily be refilled while the engine is working. The tank from which the engine takes its supply of oil will hold oil for more than a day's run.

The working of the engine is so simple, that, if the directions by the makers are attended to, the engine will run for years without giving trouble.

50. To start the engine, the heating lamp is lighted and placed under the vaporiser, and in seven to fifteen minutes, according to the size of the engine, it is ready to start. The firing lamp is then lighted. A few

strokes of the oil-pump are given by hand to pump oil into the vaporiser. This oil is instantly turned into vapour, and a few turns being given to the fly-wheel, the engine starts. The air-pump blast soon heats the firing tube; then the lamp under the vaporiser (which has heated an auxiliary tube for starting) is taken away, the heat of the explosion maintaining the vaporiser at the required temperature. The engine will run as long as supply of oil in the tank and container or the lamp will last. The makers, in testing new engines in their shops, often run them twenty to thirty hours or more without stopping. One of these engines, driving a fan for hop-drying, has made, without a single stop, runs of 54, 48, 49, and 56 hours.

51. To stop the engine, a handle is fixed to the lever which works the exhaust valve. By shifting this handle the exhaust valve is kept open—destroying the compression—and the engine stops after a few strokes. This arrangement is necessary, as the oil-engine, like all compression gas-engines, will often, when stopping, make a partial revolution the reverse way. This would be of no importance if engines were used for pumping, grinding, or for farm work; but this running back would damage the brushes of a dynamo, so to avoid this risk the above-described method of stopping has been adopted.

52. This handle on the exhaust lever is very convenient for stopping the engine from a distance by means of wire or cord.

53. The piston requires lubrication. In the smaller engines a simple drop lubricator is generally fitted; in the larger ones the lubricator is of the rotary type, and is driven by a narrow leather belt off the counter-shaft. For electric light work, grease lubricators on connecting rod big end, and crank-shaft bearings, give good results. Stauffer's lubricators are good, and might be more generally used. The makers send out printed directions for working these engines, with plans of foundation, position of water tank, &c.

54. In some cases these engines (especially if portable) are fitted with a circulating pump, to force the cooling water through the jacket. This appears to give good results, as the circulation is independent of the temperature. Messrs Priestman, of Hull, fit all their engines with forced circulation.

55. A cooling tank can be dispensed with, if a stream can be tapped at a sufficiently high level to divert sufficient water to flow through the jacket.

56. There are oil-engines in the market which require some particular oil to work with, or at least to get fair results. Some engines will only work satisfactorily with heavy oils, while others can only run with a light oil. Fortunately the Trusty oil-engine will work well with any oil that is in the market, even with the heavy lighthouse oil, which has a flashing point as high as 240° F. Besides the Trusty the Hornsby-Ackroyd, the Roots, and the Crossley oil-engines have a high reputation.

57. A few words on oil may not be out of place Paraffin or kerosine oil is a distillate of rock oil or petroleum. The oil is distilled in cast-iron retorts. The first products of the distillation are gasoline and benzoline. The former gives off an inflammable vapour at a very low temperature, possibly even below the freezing-point of water; it is consequently somewhat dangerous to handle. Benzoline has a slightly higher flashing point, giving off vapour at ordinary temperatures under 73° F.; and any petroleum that gives off an inflammable vapour under this temperature is called "petroleum" by Act of Parliament, and only a small quantity may be kept in a house or store without a licence from the police or county council.

58. By flashing point is understood the temperature of the oil at which it will give off a vapour that will take fire from a flame placed close to the surface of the oil. The instrument in general use for testing oils is known as Abel's Tester. The police in most county towns are provided with these instruments.

59. There are in the present day few oils in the market which have as low a flashing point as 73° F. Others, such as the Broxburn lighthouse oil, have a flashing point of 240°. It would seem advisable for Parliament to raise the flashing point to at least 100° or 120°. In India, and other hot countries, 120° to 140° is the limit imposed by law.

60. After the gasoline and benzoline come off in the stills the temperature is raised, and the paraffin or

kerosine oils come off. From most petroleum wells these oils—that is oil for burning—form the largest product of distillation. After the lighting oils are produced, lubricating oils and paraffin wax are obtained.

61. Dr Muspratt gives the following as the products of crude Pennsylvania petroleum :—

Gasoline	1.5
Naphtha	10
Benzine	4
Kerosine lamp oil . . .	55
Solid paraffin and lubricating oils .	19.5
Coke and loss . . .	10
	100.0

There are few countries in the world in which petroleum has not been found. The largest districts are in the United States, and in Russia, on the shores of the Caspian Sea; and it is from these countries that our supply is drawn. As the supply seems almost inexhaustible, and fresh districts are being opened up, the supply seems to be in excess of the demand. Prices have been falling for many years past, and will probably continue to fall for some time to come. The late Mr Charles Marvin's book on the Russian oil fields, under the name of "Region of Eternal Fire," is well worth reading by those who care to obtain any further information on the petroleum industry.

CHAPTER V.

FITTINGS.

62. In the present day, when electric light is so common, the householder has very little difficulty in getting an estimate for the wiring of his house, and there is no necessity for him to ask friends or experts what makers' fittings are the best. The last ten years has produced a uniformity of fittings, and the catalogues of the electric-light engineer will generally give all the information required.*

The fittings comprise wires, cut outs, switches, brackets, shades, and lamps. In very few cases would the householder care to do the wiring and fitting up the lamps himself. The author has done this in his own house, but he would hardly recommend anyone to repeat the experiment. The skilled electric light fitter is provided with tools not possessed by the amateur, and the work will be done more neatly and quickly by a fitter than is possible by one who has not been accustomed to this class of work. Besides, the wire must be done to pass the insurance company, and the electric light fitter will know what

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* Some electrical engineers issue very useful catalogues, giving a considerable amount of information, and some of these are well worth reading.

the requirements of the company are as regards insulation, and size of wire and cut-outs, &c.

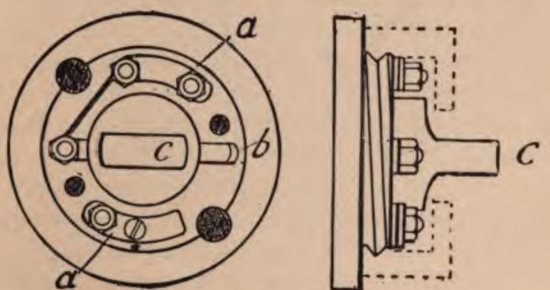
63. The cost of wiring a house and supplying good fittings in the present day, may be taken at about 25s. to 30s. per lamp, roughly speaking. This would include plain opal shades, and a few wall brackets. In the author's house all the lamps are pendant; in most cases they are arranged in the centre of the rooms over the table, and are about 5 feet from the ground; but in the drawing-room, hall, passages, and bedrooms, the height is about 6 feet 6 inches or more.

64. It must first be decided where the wires from the dynamo should enter the house; here is fixed the main switch, and between it and the dynamo the main cut-out.

65. Cut-outs are breaks in the wire provided with terminals or binding screws to hold the fuse wire which is inserted to bridge over the gap or break. Fuse wire is made of tin or lead, which melts at a comparatively low temperature. It is also a far inferior conductor of electricity than copper; and if by any chance too great a current is passed through the wire the fuse melts, and so breaks the circuit, and thus prevents any damage that might arise from this cause. A cut-out should be provided for each lamp. These are frequently placed in the switches, and covered with the porcelain cover. For 50-volt 16-candle-power lamps, tin wire of 28 S.W.G. is used.

66. The switches must be snap action, with a spring to suddenly break contact. To effect this the porcelain handle is fitted loosely on the brass point of the switch, and as soon as contact is broken the spring rapidly separates the two points. Without this arrangement the electric spark formed each time contact is broken would destroy the touching point. It is usual to fix the switches with the handles vertically when the current is on, and horizontally when it is off.

67. Figs. 3, 4 shew an ordinary switch in plan, with



FIGS. 3 AND 4.—SWITCH.

cover removed, and in side elevation. The cover is shewn by dotted lines. On unscrewing the cover four holes are noticed; the larger ones are for screwing the switch to the wood block which is fastened to the wall; the two smaller holes are for the wire to be brought in by, and connected to the two curved brass plates *a*. The handle of the switch *c*, which is pivoted on a cross-bar or plate running right across the porcelain base, moves the tongue *b* into contact with the lower curved plate, and makes the connection

for the current. This cross-bar is in connection with the other curved plate by the fuse wire, which is shewn by the thick dark line.*

The main wires are led through the house, with branches into the various rooms or passages where lamps are wanted. If possible, it is advisable to have the switches on the shutting doorpost, at a convenient height from the floor.

68. The author strongly recommends the use of the "brass-capped" lamp and the "bayonet" holder, in preference to the "bottom loop" lamp, for the following reasons:—The lamp is more readily fixed, the appearance is neater, and the contact is excellent. The faults of the bottom loop are the tendency of the little platinum loops to break, the difficulty in fixing by inexperienced persons, and the high resistance to the passage of the current to the lamp caused by the small surfaces afforded by this mode of contact.

As to the make of lamps, Ediswan seem still to keep to the front. The author has found these to be better than those of another maker that he tried.

There are doubtless lamps as good as the Ediswan, and cheaper in first cost. An excellent lamp is imported from Switzerland, and the Cruto is well spoken of.

69. The author would have thought the incandescent lamp too well known to need description; but so manyfriends who have seen his installation have been

* The switch known as the Tumbler is a very good one.

totally ignorant of what it is the lamp really consists of, that a brief description may not be out of place.

70. The filament which emits the light, and when no current is flowing looks like a piece of wire, is made of carbon. Bamboo fibre, or cotton thread, is generally used to form the filament; the thread or bamboo fibre is bent to the proper shape, and to the number of several hundreds placed in a mould, and then in a furnace for some hours; they come out carbonised, just as the charcoal burner makes his charcoal from wood which he stacks in a conical heap and burns, covering it over with sand or ashes to exclude the air.

71. The wires which take the current into the lamp are platinum, and these are the most expensive part of the lamp. Should large discoveries of this precious metal ever take place, so as to considerably reduce its price, we may expect a fall in the price of lamps. No other metal will answer like platinum, for glass and platinum expand in the same ratio. Attempts have been made in America to use iron wires, and some two years ago the American newspapers were puffing this new lamp; but at present it does not appear to have been used in England, and it is more than doubtful if it ever will. Yankees are clever people, but they cannot alter the expanding ratio of glass or iron.

72. The carbon loop, with its conducting wires, is then hermetically sealed into the bulb by the glass-

blower. The air has yet to be exhausted; it is pumped out by a mercurial air-pump, and when the exhaustion is complete, the tube through which the air has been extracted is closed by the glass-blower, and the lamp is finished.

73. These lamps are made of various voltages and various candle-power. As before mentioned, in small private installations 50 or 100 volt lamps are generally used. The 16 candle-power lamp is the one most frequently employed; but for small bedrooms, passages, 8 candle-power is quite sufficient. There is often a misconception as regards candle-power. A standard candle is one burning 120 grains of spermaceti per hour. These candles can be purchased, and tests can be made as to the light a lamp is giving; but the test must be made against a standard candle, not against an ozokerit or paraffin wax candle. Improvements in candles have considerably increased their lighting power during the last twenty or thirty years; a Broxburn mineral wax candle of 8 to the lb. will give a light equal to $1\frac{1}{4}$ standard candles.

74. The same improvement has taken place in lighting oils. A1 crystal oil, and such brands as Royal Daylight or Tea-rose, give a better light than the oils formerly burnt.

75. In wiring a house it is sometimes difficult to decide where the lamps should be placed. Sir D. Salomons recommends the experiment of placing a

duplex oil lamp (or lamps) in various positions in the rooms to be lighted, and when the best positions have thus been ascertained, to fix the electric lamps accordingly.

In a dining-room there can be no doubt the lamps must be over the table. Electric candelabra are also much used, the conducting wires being brought under the table from a wall socket, contained in a little trap-door in the floor under the table. If these "candle" lamps are tastefully shaded a very pretty effect is produced, but the connection of the wires involves some trouble, and this last-described method is not so simple as the former.

In a drawing-room, study, or bedroom, each householder must decide for himself or herself; the furniture of the rooms, the habits of its occupants, must be taken into consideration.

In the author's house several mistakes were made, and several lamps had to be shifted after a short time.

76. The choice of shades and brackets is a matter of taste. Some extremely beautiful ones may be seen in the show-rooms of the dealers in electric light fittings. It must be remembered that a globe or shade may appear suitable when seen in the shop or show-room; but when in place intended for it may cause disappointment to the purchaser; it would be as well to have some of various patterns sent on approval.

An ordinary opal shade, with chiffon (a very fine muslin) on the top, and hanging some six or more

inches below (like a petticoat), has a very good effect, the light is softened and diffused. This is shewn in Fig. 5.

77. Frosted lamps are often used, they diffuse the light more than clear glass, but absorb a small amount of light.

78. Unless it is intended to use accumulators, it is

FIG. 5.—OPAL LAMP SHADE.

hardly necessary to go to the expense of a switch-board. The object of the switch-board is to connect either the dynamo to the accumulators in order to charge them, the dynamo direct to the lamps in the house, or the accumulators to the lamps in the house. Switch-boards are generally made of slate, and have the voltmeter and ammeters fixed on them, and also

the charge and discharge switches for the regulating cells of the battery.

79. The voltmeter, as explained before, is really a galvanometer graduated in divisions which represent volts. They are of various forms, but the most usual consist of a small piece of iron pivoted between the legs of a horseshoe magnet, and surrounded with a coil of very fine German silver wire, a wire which has a very high resistance.

The current deflects the pivoted iron from the magnet poles (just as a magnetic needle is deflected from the poles of the earth by a current of electricity), and the amount of the deflections correspond to the voltage of the current.

80. The voltmeter should be fixed in the dynamo-room, about 5 feet or 5 feet 6 inches from the ground. If the dynamo-room is an iron shed, the voltmeter should not be fixed near to the iron, but must be blocked out for some inches by pieces of wood, otherwise the proximity of the iron of the shed might vitiate the readings.* Voltmeters cost from £2. 10s. to £5. Only a small portion of the current flows through the voltmeter. A small push, like an electric bell-push, is frequently used to send the small quantity of current through the instrument when it is required to take a reading.

81. The ammeter, on the other hand, has the whole

* There are several voltmeters made which are not affected by the proximity of iron or magnets.

of the current passed through it. An ammeter is not absolutely necessary, but it is a great advantage, as by reading both instruments the man in charge of the machinery can tell if engine and dynamo are working properly.

82. In Chapter II. the volt and ampere have been alluded to. A 16 candle-power lamp requires 1·2 amperes to properly light it at 50 volts. $1·2 \times 50 = 60$, *i.e.*, 60 watts,—the product of volts multiplied by amperes being termed watts. 4 watts give one candle-power. If the voltage of the current is 100, ·6 amperes only are required to light the lamp.

The man in charge of the machinery, by reading these two instruments, can tell fairly well the number of lights in use, and consequently the power exerted by his engine. It is usual to allow ten 16 candle-power lamps for each actual or brake horse-power exerted by the engine.

83. In putting down electric light plant, especially in a new house, it is worth while to consider whether the engine can be used for pumping or any other purpose. There is no reason why an engine should only run five or six hours a day, when often, by a little consideration, other employment can be found for it. In the author's case the engine is used for pumping from a deep well for about three hours every third or fourth day; in summer, however, it is in almost daily use pumping for garden purposes. Of course the power required for pumping is small, about

$\frac{1}{4}$ or $\frac{3}{8}$ of a horse-power, but still some motive would be necessary.

Modern dairy work requires power to drive separators, and machinery for preparing food for cattle could be worked by the engine.

If the engine be used for other purposes than electric light, the whole cost of the engine should not be debited to the electric light. One-fourth or one-half, according to circumstances, must be debited to the dairy or other work the engine has to do.

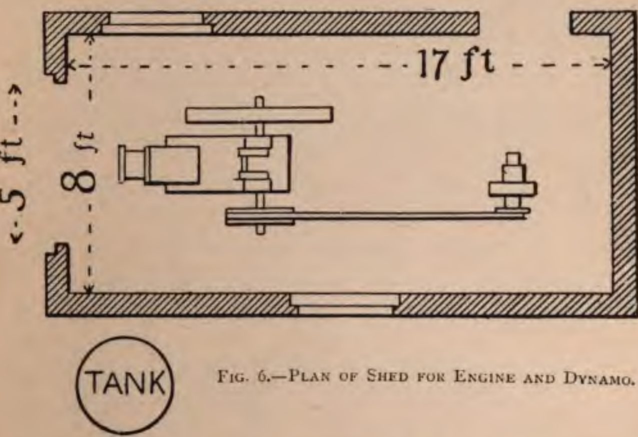


FIG. 6.—PLAN OF SHED FOR ENGINE AND DYNAMO.

84. Fig. 6 shews (in plan) a shed for engine and dynamo for thirty lights. It is 17 feet by 8 feet, this allows plenty of room for engine and dynamo, the height to eaves is 6 feet, roof slate on boards. The cost of such a building would be about £37.

The end doors, with 5 feet opening, enable the engine to work any machinery, such as a saw bench,

that can be placed out of doors; the doors permit the engine being removed at any time if it is desired to do so.

The engine must be firmly bolted down on its concrete bed. Instructions for fixing the engine are sent out by the makers.

85. The machinery ought to be in charge of one man, who should be responsible for its working; dual control in electric light machinery, as in other matters, is not generally successful.

The author believes that in most cases an intelligent labourer, who will carefully follow the instructions given him, will do better than a skilled mechanic. Many small installations are worked (as the author's is) by gardeners, who as a class seem well adapted for the work, their daily occupation having induced habits of observation.

86. When the engine is started at dusk, a visit once or twice in the evening is ample, just to feel the bearings and see that all is right. Should the attendant live on the premises, a lamp placed in his cottage would by its light beginning to fail at once tell him that something was wrong.

87. If, however, a steam-engine is used, the attendant can hardly leave it for a quarter of an hour (unless it be such a motor as the Davey or Bailey-Fredrich). In this case the wages entailed by the employment of a steam-engine will soon cover any saving that might have been effected by purchasing

the cheaper steam-engine in place of the oil-engine. Taking the man's wages as low as 3½d. per hour, and the machinery to be running five hours each evening including time occupied in getting up steam, this will amount to £26 13s. in the course of the year. With an oil-engine, three-quarters or one hour is ample for starting it, and for keeping it in good order. This will be less than the time taken to trim, clean, and fill twelve or fifteen paraffin lamps; so that in taking the cost of working, as given in a following chapter, the amount for labour is omitted, being more than balanced by time saved in attending to the lamps.

88. The exhaust from a steam-engine has often been used for heating a greenhouse, by carrying the exhaust pipe round the interior of the building. There is no reason why the cooling water from a gas or oil engine might not be used for the same purpose, at least as an auxiliary to the ordinary boiler or stove. Of course, unless a circulating pump is fitted to the engine it would be necessary to have the engine at a lower level than the greenhouse. Any person who has placed his hand at the top of an oil or gas engine cooling-tank towards the end of its day's work, will realise how much heat is necessarily wasted by being carried off in the water jacket.

89. An objection has been raised to the smell of oil-engines, and a few years since such objection would be perfectly valid; but now that the conditions under which the oil is consumed are better understood, and makers have realised that to get full value for the oil

burnt the combustion must be perfect, the smell from the engines is extremely slight. In the author's case, the engine is some twenty-five yards from the dwelling-house, on the west side, and although two or three upstairs windows face that direction there is no objectionable smell perceived.

90. In some cases the noise of the exhaust may be a nuisance. This is considerably softened by using a

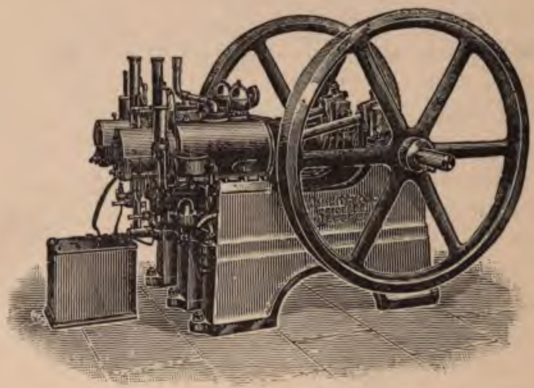


FIG. 7.—DOUBLE-CYLINDER TRUSTY OIL-ENGINE.

second silencing chamber. In dry weather the exhaust is almost invisible ; in wet, damp weather it is generally seen as a puff of white steam. This really is aqueous vapour from the atmosphere, and not unburnt oil, as some have imagined.

91. Fig. 7 shews a double-cylinder Trusty oil-engine, which may be compared with the single-

cylinder engine of the same make, shewn in the frontispiece. The double-cylinder engines are made to give eight brake horse-power and upwards, and there being two cylinders, there is consequently an impulse every revolution. They are well suited for electric light purposes. An engine of this class would be well adapted for village lighting. For such work, if it were considered admissible to have some lights on all night and early morning, it would be best to have two engines, one of 16 B.H.P. and one of 3 or 4. The large one would easily run 150 lights, and this engine would be driving the dynamos from dusk till about midnight, when nearly all the lights would be out; then the smaller engine would be started and run till daybreak. If at times it was anticipated that more than the usual number of lights would be wanted, such as on occasions of parties, balls, or entertainments, both engines would be employed if necessary. One of the engines might be used for pumping water for the village supply during the day.

The cost of a village electric light plant, with either oil or steam power, would compare favourably with the outlay for small gas-works.

CHAPTER VI.

COST.

92. It has been mentioned before, that the cost of wiring, lamp, &c., is approximately 25s. per light. The cost of the plant is a more serious item, and may be roughly set down at anything from £4 to £10 per light for small installations, and somewhat more if accumulators are used. The following table gives the cost of four small installations for 10, 18, 30, and 45 lights. The two last might certainly run a few more lamps, but they have been put down at 30 and 45 lamps respectively, as 35 and 50, which the dynamos could do might be rather too much for the engines, so the table has been drawn up to allow ample margin for power.

93. If a steam-engine is used the cost would be considerably reduced; but, as shewn in the previous chapter, the wages would amount to a serious item. Thus in eighteen months or two years the saving would have disappeared; besides, few small steam-engines are really economical, and at the present price of oil (4¾d. to 5d. in London) no small steam-engine can compete with the oil-engine, unless, by proximity to collieries, coal can be bought at a very low price.

TABLE I.

COST OF 10, 18, 30, AND 45 LIGHT INSTALLATIONS.

	10 LIGHTS.			18 LIGHTS.			30 LIGHTS.			45 LIGHTS.		
	1¼ B. H.-P.			2¼ B. H.-P.			3¼ B. H.-P.			4¼ B. H.-P.		
	£	s.	d.	£	s.	d.	£	s.	d.	£	s.	d.
Trusty Oil-engine .	62	0	0	71	5	0	85	10	0	100	18	0
Water Tank . . .	2	5	0	2	10	0	3	0	0	3	10	0
Dynamo	21	3	0	30	3	0	40	1	0	46	2	6
Belt	1	10	0	1	15	0	2	0	0	2	5	0
Am. and Voltmeter	5	0	0	5	0	0	5	0	0	5	0	0
Switch and Cut-out	1	0	0	1	0	0	1	0	0	1	10	0
	93	8	0	111	13	0	136	11	0	159	5	6

The cost in the above table has been taken at 5 per cent. less than makers' list price for engines and dynamos. The price for dynamos includes fly-wheel, slide rails, and tightening screws, but no estimate is made for fixing, the cost of this depending so much on local circumstances. The outlay for the water tank may be omitted if a water supply sufficient to cool the cylinder can be obtained. If, on the other hand, the engine is fitted with a circulating pump, a pound or two extra will be required. There might be in many old country houses some outbuilding that,

with but little alteration, could be turned into a convenient engine-house.

94. A 4 H.P. Trusty oil-engine, giving 6 B.H.P., tested in 1893 by Mr W. Worby Beaumont, M.I.C.E., consumed .82 pint of oil per B.H.P. per hour. Even in the smaller engines given in the table, the oil consumed would not exceed 1 pint per B.H.P. per hour.

95. The cost of one night's working of five hours would, for the 30-light plant, be somewhat as under:—

	s.	*d.*
Interest and depreciation* - - -	1	0
$17\frac{1}{2}$ pints of oil at 5d. per gal. - - -	0	11
Lubricating oil, grease, waste, &c. - -	0	2
	2	**1**

For this, if all the lamps were glowing for the whole five hours, would be :—25 pence divided by 30 lamps running five hours :—

$\frac{25}{30 \text{ by } 5} = \frac{25}{150} = \frac{1}{6}$ of a penny per lamp per hour.

96. This would include all running expenses. The depreciation would cover and allow for new brushes for dynamo, new firing tubes, and a general overhaul of engine every three or four years.

97. To this must be added lamp renewals. The lamps are said to have a life of 1,000 hours, and running an average of five hours each evening all

* Interest and depreciation at $12\frac{1}{2}$ per cent. on £150 comes to £18. 17s. per annum, a trifle over 1s. per day.

through the year give 1,825 hours; but as all the lamps will not be in use all the time, two-thirds of the lamps may be expected to require renewal each year, and as the lamps are now obtained at 1s. 9d. each and under this is not a very serious item.

98. It must be understood that unless all the 30 lamps were running the whole five hours, the figures alone would not work out as low as $\frac{1}{8}$d. per lamp per hour. Thus the actual cost would be more nearly $\frac{1}{6}$d. or $\frac{1}{4}$d.

99. The cost may be shewn in another way:—Gas is sold by the 1,000 feet; oil by the gallon or barrel. Electric current is sold by the companies by the Board of Trade unit—that is, 1,000 watts. It has been mentioned above that a 16 candle-power lamp takes 60 watts; so that a 16 candle-power lamp glowing for 16 hours and 40 minutes (for $16\frac{2}{3} \times 60 = 1{,}000$) has consumed a Board of Trade unit, generally expressed B.T.U.

Now our installation, with running expenses of 2s 1d. per night, if lighting only 25 lamps, would cost $3\frac{1}{3}$d. per B.T.U., if all lamps were in use something less. Now a B.T.U. costs generally 7d., very often 8d., when electricity is supplied by the companies; so that there is a good margin of economy in running even a small private plant, at least when a reliable oil-engine is used.

100. If however a portion of the wages of the man who has charge of the machinery is to be added to

our estimate, the running expense must be set down at 2s. 6d. or 2s. 7d., and the cost of light correspondingly increased.

101. The figures given above are taken from tests made on the oil-engine not only by Mr Worby Beaumont, but also by the makers. The number of lights that an engine of given power will run is well known to any who have had some experience with electric light; besides, these figures are borne out by the experience and experiments of the author with his small installation, with a 1 nominal H.P., during the past year.

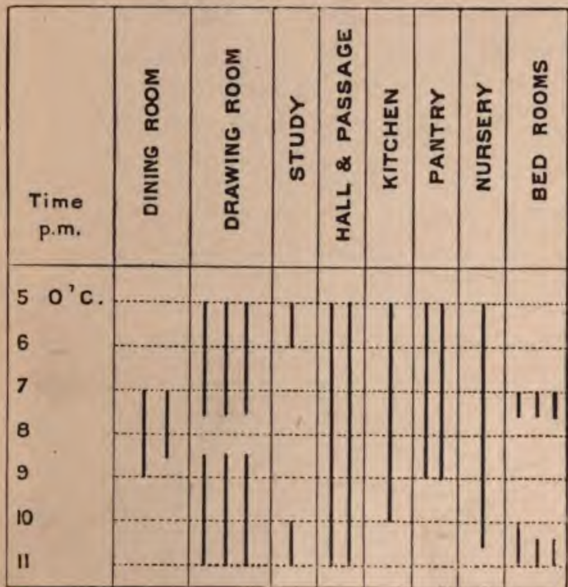
102. The following table shows the times of lighting and shutting off the light in various rooms of the author's house from 6 P.M. till 11 P.M. The vertical lines shew the duration of the light; the thin horizontal lines the hours.

It will be noted here that for a very short time only (that is just before dinner) are nearly all the lights in use; during dinner the three lights in the drawing-room are switched off.

103. If the reader who proposes going in for electric light will compile a similar table for his guidance, he will see what his requirements are. It is not unusual to hear a man say, "If I had electric light in my house I should want twenty or thirty lights, as the case might be, for I have nearly that number of lamps, and then there must be electric lamps in some of the bedrooms." But if the lamps in use do not exceed

the number the dynamo can drive, there is not the slightest reason why a few more should not be installed. Bedroom lamps are seldom used till some others are switched off. Dining-room and study are seldom used at the same time. If two lamps are wanted in a room, but not both at the same time, either lamp can be switched on by a two-way switch. This

TABLE II.
TIMES OF LIGHTING IN VARIOUS ROOMS.



arrangement is useful for bedrooms, one lamp being over the toilet-table and the other at any desired place.

104. A few words may not be out of place regarding the author's installation. Some five or more years since a 1 H.P. oil-engine of somewhat an experimental type was put down for pumping from a deep well to the top of the house. Shortly after this, experiments were made with accumulators, not so much with any idea of house lighting, but to make an accumulator that should be durable and stand roughish usage, and not to interfere with existing patents. As the latter was rather difficult to accomplish, it was determined to light the house without accumulators, driving direct. It was therefore necessary for the engine to run four or five hours without any attention, except once or twice during the evening. The gardener starts the engine before leaving work in winter, or later as the season advances, visiting it about 8.30 or 9 P.M., when he attends to the conservatory fires, just to see that all is right. The engine is stopped generally about 11 P.M.

After about three and a half years' experience of electric lighting in his own house, the author would be sorry to go back to lamps. The engine having been altered several times for experiment, a strict account of necessary repairs has not been kept, but these probably have not exceeded 30s. to 40s.; and of that amount, one-third should be debited to pumping, the engine being used for supply of water to house, laundry, and stables.

CHAPTER VII.

ACCUMULATORS.

105. It must be understood that accumulators are a very valuable adjunct to an electric light plant, as a stand-by during a temporary breakdown of the plant, or for use during the night if a few lamps are required, and for the early mornings in the middle of winter; but, it has been shewn in a previous chapter, it is perfectly possible to do without them. The first objection is their great cost. For the installation quoted in the previous chapters, at least £30 to £50 must be added if accumulators are used. The accumulators that have been in use for the longest time—some eight or ten years—are the E.P.S. cell (Electrical Power Storage Co.). These cells, which are probably as good as any others, require frequent renewals or repairs, so that the author considers that 10 to 12 per cent. would not be too much to write off for depreciation each year.

106. An accumulator or storage battery, sometimes called a secondary battery, does not, as its name would imply, actually store electricity. An electric current is sent through it, and this produces a chemical change in the plates and in the solution in which

they are immersed. When the plates are disconnected from the source of electricity, they are found to be in a condition to discharge a current, but of course of less energy and strength than that with which they are charged. If two strips of lead, three or four inches long and an inch or two wide, are separately immersed in dilute sulphur acid and connected to a battery, or for a few minutes to a current from a dynamo, the plates will have undergone a change which is plainly visible to the eye. The strip of lead connected to the positive wire will be a dark chocolate colour, the other a slate colour ; but the nature of the surface of the plates will be changed, they will be electro-positive and electro-negative, and will ring an electric bell, give sparks, &c. This is the principle of Plantè's accumulator, devised by M. G. Plantè some thirty years since, but never patented ; in fact it is very doubtful if the inventor could have any idea of the future then in store for the secondary battery. Plantè's battery required "forming,"—that is, subjecting it to a series of charging and discharging during some months,—after which time it is found to be capable of receiving a charge far in excess of what it would in the first instance. The forming has been found to have been accelerated by dipping the plates in nitric acid before commencing to use them, also corrugating them and roughening them. Howell's, and also Epstein's, accumulators belong to this class.

107. The great improvement which may be said to have first made the secondary battery a practical success was that of Faure's, viz., coating the plates

with a salt of lead, generally red lead or minium. This, under the action of the current, is turned into peroxide of lead, and offers enormous surface to the electrolyte or fluid in which the plates are immersed. Subsequent patents for improvements, for holding the lead paste in place, were taken out by Faure and others, and these patents are held by the E.P.S. Co., who claim the use of accumulators with salts of lead applied to lead plates. These E.P.S. cells are in use in thousands of places, and are used not only for lighting, but for telegraphing, for electric launches and tram-cars, and for many other purposes.

108. The Lithanode accumulator has a very good reputation. In this the lead is cast round the pellets of exciting material, which are firmly gripped in the cast-lead plate, and not likely to fall out with rough usage. The manufacturers are the Lithanode and General Electric Company, Millbank Street, Westminster. The "master" patents for the use of coated plates will very shortly expire, and then, doubtless many makers will enter the market, and a considerably cheaper cell will be obtainable.

109. Accumulators give a working E.M.F. of 2 volts, so that if 50 volt lamps are used in an installation, 25 cells will be required; but in practice 26 or 27 must be used to avoid loss of light in the leads and wires, and to increase E.M.F. when the battery is nearly discharged.

110. There is a considerable loss in using accumu-

lators; they will not return all the current put into them. The makers claim that they will give a return of 85 or 90 per cent., but in actual use 70 to 75 would possibly be all that could be obtained in everyday work.

111. The cells are coupled up positive to negative. It is usual to paint the positive terminals red, and care must be taken to see that the positive wire from the dynamo is taken to the positive end of the series. Any carelessness in this respect might ruin the accumulators.

112. As the electromotive force of 25 cells is 50 volts, and for use 27 may be required, the dynamo must be so run as to give a higher E.M.F. when charging the cells than when simply lighting the house. There must be a self-acting magnetic cut-out to break the circuit should the speed of the dynamo fall so as to fail to give sufficient E.M.F. to charge the cells, for the current from the cells would then overpower that of the dynamo,—they would discharge themselves through the dynamo, making the dynamo a motor for the time being.

113. In the mechanical storage of power, it is immaterial whether the power be stored slowly or rapidly. The power required to fill a tank with water is the same whether it be filled in one hour or in twelve; but with electric accumulators the rate of charging given by the makers must not be exceeded, otherwise the plates will be injured. The same may

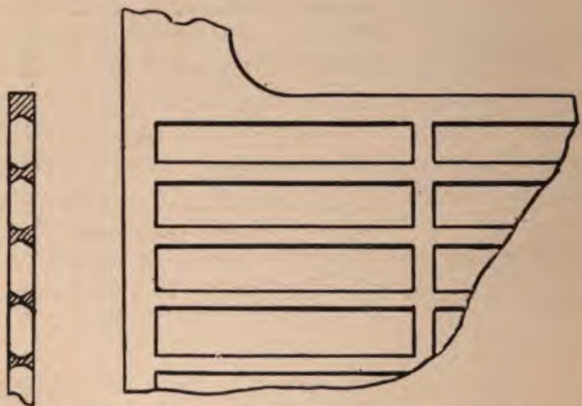
be said of discharging. Means for remedying these defects and inconveniences will doubtless be provided in the near future.

114. The capacity of accumulators is expressed by the term ampere hours, but this expression conveys no meaning unless electrical measurements are understood.

If it is required to light twenty-five 16 candle-power 50 volt lamps for five hours, a battery of accumulators of the following capacity would be wanted:—It has been shown that a 50 volt lamp requires 1.2 amperes, therefore twenty-five lamps, multiplied by five hours × 1.2 amperes = 150, *i.e.*, ampere hours, therefore 25 to 27 cells of 150 ampere hours capacity would be wanted. Of course if the lamps in use are 100 volt lamps, we should require accumulators of half the capacity, but 50 to 54 cells in place of 25 or 27, to give twice the E.M.F.

115. The construction of a dynamo or gas-engine requires a considerable amount of mechanical knowledge and skill. A good lathe is absolutely necessary, with, if possible, a shaper or planing machine; therefore, notwithstanding sundry pamphlets on "how to make a dynamo," the author thinks that very few even fair dynamos have been turned out by the amateur. Not so with the accumulators; comparatively little mechanical skill is required, and no expensive machinery, simply a tedious repetition of work, the greater part of which can be done by a perfectly unskilled labourer.

At present the Faure and other patents are in force, but as they will shortly expire, a short description of a method of casting plates and fitting them up, devised by the author, may be of interest to some. Sheet-lead plates, roughened and perforated, have often been recommended and described, but the author has failed to get as good results as he expected with these.



FIGS. 8 AND 9.—SECTION AND PLAN OF PLATE.

116. Figs. 8 and 9 shew a section and plan of the plate. It is three-sixteenths thick, and the spaces into which the red lead is forced are grooved at both top and bottom, so that the active material is gripped for its length, but not at the ends.

Fig. 10 shews the mould, or rather one-half of it, with the cores in place. These cores are made from iron bar three-eighths in width and three-sixteenths thick. They are bevelled at both sides, at top and

bottom, and on underside are two pegs to fit into holes in the bottom of the mould. A core is shown in Fig 11.

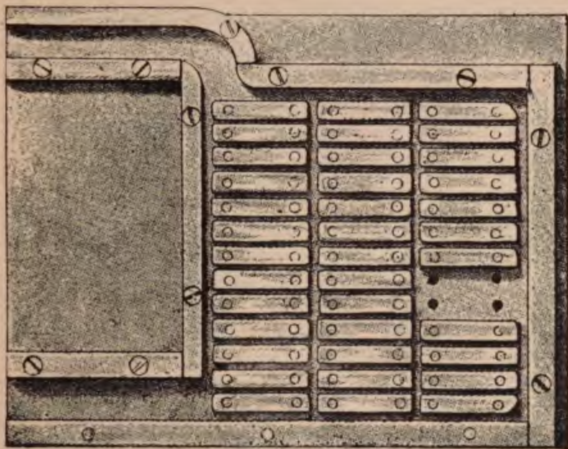


FIG 10.—ACCUMULATOR MOULD.

(Top Plate removed. For casting, the mould is placed vertically, and the lead run in through the gates shewn on the left. The curved passage forms the lug for connection.)

The cores are all placed in the mould and the lead poured in, the mould having previously been heated; the cores all come out with the casting. The casting

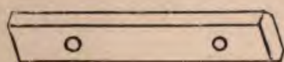


FIG 11.—CORE.

is then placed on a block of wood in which a gap has been cut, and the iron cores driven out with a hammer

and punch, and drop into the gap in the block. Driving out the cores disfigures and curves the plates, and the edges are then beaten back to the original position with a light hammer, as shown in Figs. 8 and 9.

The plates described here are 7 inches square, and 7 plates go to a cell, so that for a 50 volt circuit 27 cells will be required, or 189 plates in all. It is advisable to cast four or five extra, as some plates may be found to be defective when putting the battery together.

117. When all the plates are cast they are filled with red lead, made into a paste with dilute sulphuric acid. If concentrated acid is used, the paste will take a very long time to dry and harden. About 1 of acid to 4 of water seems to be a proper proportion. The paste is worked into the plates with a wooden trowel, somewhat like that used by plasterers. The pasted plates must then be set up on edge to dry.

In dry summer weather, they can be dried in the open air; in winter or damp weather, in a room with a stove, with plenty of ventilation to carry off the acid fumes. They will take three or more days to dry, according to the temperature or state of the atmosphere. The plates in their glass cells rest on combs or racks of hard wood, which have been soaked in hot paraffin wax. A similar rack is required on the top of the plates to keep them apart. The lugs are clamped together by brass bolts and nuts. It is usual in accumulators to lead-burn the connections. To do this a hydrogen frame is necessary, and it

doubtless requires considerable skill. The author has found the clamps to answer well. They have one advantage over the lead-burned plates, that a defective plate can be taken out and replaced with comparatively little trouble. The lugs and clamps must be coated with two or three coats of varnish to prevent acid fumes attacking.

The glass cells are rather difficult to procure, and are imported here from Germany. They can be obtained through Messrs Becker & Co., of Hatton Wall, London.

118. When the whole battery is set up, and filled with dilute sulphuric acid of specific gravity 1.8, the first charging or forming charge must be given. The first charging will differ from subsequent chargings, as the red lead has to be turned into peroxide of lead by the action of the current. For the first charging a current of about 8 amperes (for the above-described cells), and lasting from eighteen to twenty hours, would probably be sufficient.

The above-described cells, if the plates are 7 inches square, and 7 plates in each cell, would have a capacity of at least 30 ampere hours. As the charging proceeds, the specific gravity of the liquid, technically termed electolyte, is lowered, so that by testing with a suitable hydrometer it is possible, and is at least the only reliable way, to estimate the change in the cells. After the cells have been properly formed, bubbles of gas are given off when charging is nearly complete. Some cells of a series will often bubble or gas before others, but when they are all gasing it is a sign that the cells have received their full charge.

119. If the reader desires to go into the question of accumulators more fully, he can turn to Sir D. Salomons' book, or to "Secondary Batteries" by Niblet (published by Biggs).

APPENDIX.

INSTRUCTIONS FOR WORKING A DYNAMO.

ELECTRICAL AND OTHER TERMS EXPLAINED.

INSTRUCTIONS FOR WORKING A DYNAMO.

Foundation.—This should be of stone or concrete, and of ample size to minimise vibration. The dynamo should be mounted on slide rails, to facilitate the adjustment of the belt.

Belting.—Good single leather belting gives very good results. The direction of the drive should be so arranged that the tight or driving side should be underneath. It is most important that a dynamo-belt should run evenly. A butt joint should be used, as the end of the belt in a lap joint causes a jar when passing over the pulley, often sufficient to produce a perceptible wink in the lights, besides setting up an injurious vibration. Do not run with too tight a belt.

Brushes.—These should be set at diametrically opposite points of the commutator, and brought forward as they wear, care being taken that their proper level is maintained. Move the rocker or brush-holder round till that point is found where least sparking takes place. Always keep the pressure of the brushes on the commutator as light as is consistent with proper working, and the avoidance of jumping.

Commutator.—This may occasionally be cleaned

with a little fine and preferably old emery-cloth. On no account oil the commutator; a very little mineral oil may, however, be applied with a rag; the use of a very little vaseline is recommended.

Flats on Commutator. — These are frequently caused by vibration of the machine itself, caused by insufficient foundation, or by a badly running belt, or sometimes by some defect in the insulation of the armature coils. If caused by the latter, it may be discovered by the flats always appearing in the same place, and the fault must be tested for. After removing the cause, the flats, if not very deep, may be eradicated by carefully filing down the high parts of the commutator with a smooth file. This must not be done by holding and pressing a file on the commutator as the machine is turned round by hand, for the file would sink into the worn depressions, and but little good would be done; the high parts must be carefully brought down to the low parts, care being taken that the commutator is kept cylindrical, and contains no flat places or depressions. If the flats are very deep, recourse must be had to a lathe; a pointed tool should be used, and a very light cut taken.

Oiling.—A *copper* oil-feeder should be used; if sight-feed lubricators are used, they should be adjusted to feed from three to ten drops per minute according to circumstances.

Do not leave iron tools near the dynamo, as the magnetism may draw them to it; for the same reason be careful of one's watch, or it will be magnetised; *last, but not least*, a dynamo cannot be kept too clean.

ELECTRICAL AND OTHER TERMS EXPLAINED.

Accumulator.—A secondary battery which, when charged by a current from a dynamo or primary battery, undergoes a chemical change. By this means a so-called electrical charge is stored in the accumulator, and given out when required.

Alternating Currents. — Currents consisting of waves of electrical energy in alternate directions, rapidly following each other, sometimes as frequently as seventy to eighty or more alternations per second.

Ampere.—A measure of current (a current of one ampere will deposit 18·2 grains of copper per hour in a solution of sulphate of copper). Amperes multiplied by volts give the energy of the current.

Ammeter.—An instrument for measuring amperes.

Arc, Arc Lamp.—The original form of electric light discovered by Sir H. Davy early in the present century. It is produced by a powerful current between carbon rods. In an arc lamp suitable mechanism maintains the rods the proper distance apart, and causes them to feed forward as they are consumed.

Armature of Dynamo.—The rotating mass of wire

on a dynamo, consisting of conducting copper wire wound over a mass of iron in the form of wire or thin stampings, called the core.

B.H.-P. (Brake Horse-Power).—The actual horse-power of an engine, as given off by a brake or dynamometer.

Circuit.—The path taken by the electric current from a source of electricity, and its return.

Circuit (Short).—A conductor or wire leading from one pole of a battery to the other, or from one terminal of a dynamo to the other.

If the two wires leading to a lamp are in contact, they are said to be short circuited, and no light is produced in the lamp; or if the two plates of a battery touch each other they are short circuited; in both cases energy is lost.

Commutator of Dynamo.—The copper segments to which the wires from the armature are attached, and from which, as it revolves, the current is led off by brushes of wire or gauze.

Conductor.—Any metal or substances that will conduct or permit electricity to pass. All metals are conductors, copper and silver being the best, also liquids, damp earth, &c. The human body is a partial conductor.

Cut-out.—A piece of mechanism to cut-out a lamp or circuit, should the current be too great for that lamp or circuit to bear. They are generally made of wire, such as tin, that will melt, and so break the circuit of which they form part, before the current is too great to do damage.

Dynamo.—A machine consisting of coils of wire

and magnets for producing electricity from motive power.

Electric Horse-Power.—A current equal to 746 watts.

Field Magnets of Dynamo. — The fixed or stationary magnets of a dynamo.

Fuse.—The tin or alloy wire used in the cut-outs.

Galvanometer.—A magnetic needle surrounded with a coil of wire, the needle being moved by a current sent through the wire it gives the strength of the current.

H.-P. (Horse-Power).—A term used to express the power of steam and other engines; it was fixed by James Watt at 33,000 lbs., *i.e.*, lbs. lifted one foot high per minute; but this is considerably more than a horse could exert in everyday work. However, for short periods, such as starting a tramcar, or taking heavy loads up steep hills, a horse can exert considerably more than one mechanical horse-power.

I.H.P. (Indicated Horse-Power).—The power of an engine as read by the indicator. This includes the power absorbed by the engine in turning itself round; it is the total power exerted in the engine.

Incandescent Lamp.—Lamps with a filament of carbon which is rendered incandescent by the resistance of the electric current passing through it. To prevent the destruction of the filament by combustion, the glass bulb is exhausted of all air.

Insulator or Non-Conductor.—All substances through which electricity cannot pass, such as glass, porcelain, india-rubber.

Induced Current.—A current produced by the action of another current, or by magnets. Induction coils and transformers produce induced currents.

Non-Conductor.—*See* Insulator.

Ohm.—A measure of resistance to the passage of electricity. All substances offer resistance to the passage of electricity, and this resistance can be measured, and is expressed in ohms.

Resistance.—The resistance of a conductor may be compared to a long pipe with water flowing through it,—the larger the pipe, and the smoother its internal surface, the greater the quantity of water delivered; so with electricity, the less the resistance the greater the current.

Secondary Battery.—*See* Accumulator.

Switch.—An apparatus for turning on or off the current.

Tension.—A term synonymous with voltage or electro-motive force; thus high tension currents are currents of considerable voltage or high electro-motive force.

Transformer.—A piece of apparatus to lower the high tension of a current to one of much lower electro-motive force, for use in houses where it would not be safe to employ the high tension current. They are also used for raising a current generated at a low tension to a high one for transmitting the energy to a distance and other purposes.

Volt.—A measure of electro-motive force, nearly equal to a Daniel cell, no matter what the size of the cell is. The electro-motive force may be compared to the head of water in a tank, but the head of water

does not express the number of gallons in the tank; or the electro-motive force may be compared to the pressure of steam in the boiler, but the pressure of steam in no way indicates the power of the boiler.

An accumulator gives an electro-motive force of two volts.

Voltmeter.—An instrument for measuring volts.

Watt. — The product of volts multiplied by amperes. A 16 candle-power Edison and Swan lamp absorbs 60 watts.

INDEX.

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